

(43) Date of A Publication 30.05.2001

(21) Application No 0023327.0

(22) Date of Filing 22.09.2000

(30) Priority Data

(31) 99119114 (32) 04.10.1999 (33) EP

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(51) INT CL⁷

C07C 43/225, C09K 19/20 19/46, G02F 1/13

(52) UK CL (Edition S)

C2C CAA
C4X X12 X12TP
U1S S1337 S1343 S1367 S1387 S1529 S1917 S1918
S1921 S2120 S2234 S2285

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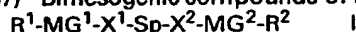
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(54) Abstract Title

Bimesogenic compounds and their use in flexoelectric liquid crystal devices

(57) Bimesogenic compounds of formula I are provided



wherein

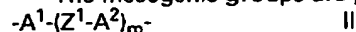
R^1 and R^2 are each independently F, Cl, CN, NO₂, NCS, -S-CN, -O-CN, or a straight-chain or branched alkyl group with 1 to 25 C atoms which may be unsubstituted, mono- or polysubstituted by halogen or CN, it being also possible for one or more non-adjacent CH₂ groups to be replaced, in each case independently from one another, by -O-, -S-, -NH-, -N(CH₃)-, -CO-, -COO-, -OCO-, -O-CO-O-, -S-CO-, -CO-S-, -CH=CH-, -CH=CF-, -CF=CF- or -C≡C- in such a manner that oxygen atoms are not linked directly to one another;

MG^1 and MG^2 are each independently a mesogenic group;

Sp is a spacer group comprising comprising 5 to 40 C atoms, wherein one or more non-adjacent CH₂ groups may also be replaced by -O-, -S-, -NH-, -N(CH₃)-, -CO-, -O-CO-, -S-CO-, -O-COO-, -CO-S-, -CO-O-, -CH(halogen)-, -CH(CN)-, -CH=CH- or -C≡C-; and

X^1 and X^2 are each independently -O-, -S-, -CO-, -COO-, -OCO-, -O-CO-O-, -CO-NH-, -NH-CO-, -CH₂CH₂-, -OCH₂-, -CH₂O-, -SCH₂-, -CH₂S-, -CH=CH-, -CH=CH-COO-, -OCO-CH=CH-, -C≡C- or a single bond.

The mesogenic groups are preferably of formula II



wherein

m is 0,1,2 or 3;

Z^1 is a conventional linker; and

A^1 and A^2 are conventional ring systems as defined in claim 2.

These liquid crystal materials may be used in flexoelectric displays which have good uniform alignment over the entire area of the display cell without the use of a mechanical shearing process, good contrast, high switching angles and fast response times also at low temperatures. The liquid crystal materials exhibit low melting points, broad chiral nematic phase ranges, short temperature independent pitch lengths and high flexoelectric coefficients.

(57) continued overleaf

(56) cont

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(58) Field of Search
Online: CAS ONLINE

(57) cont

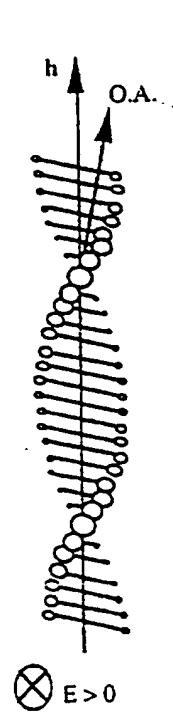
By using a flexoelectric display cell comprising two transparent, plane parallel electrodes with hybrid alignment conditions, i.e. homeotropic alignment on the first electrode surface and planar alignment on the second electrode surface of the cell, improved flexoelectric switching performance of the display, in particular high switching angles, fast response times and good contrast can be achieved with stable alignment.

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Helical axis, h ,
optical axis, $O.A.$

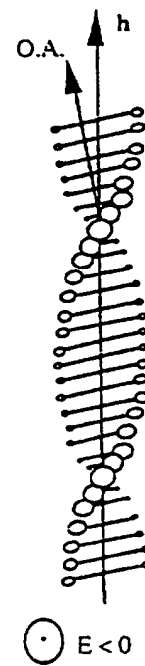
 $E = 0$ 

Figure 1

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Bimesogenic Compounds and Flexoelectric Devices

5 The invention relates to bimesogenic compounds, their preparation and their use in liquid crystal media and devices, in particular in flexoelectric liquid crystal devices. The invention further relates to liquid crystal media and devices, in particular flexoelectric devices, comprising bimesogenic compounds and to improvements in flexoelectric devices.

10 Flexoelectric liquid crystal materials are known in prior art. The flexoelectric effect is described inter alia by Chandrasekhar, "Liquid Crystals", 2nd edition, Cambridge University Press (1992) and P.G. deGennes et al., "The Physics of Liquid Crystals", 2nd edition, Oxford Science Publications (1995).

15 Flexoelectric distortion can occur in a material comprising molecules with an asymmetric shape and a strong electric dipole moment upon application of an electric field. When no field is applied, the material is undistorted and exhibits no bulk polarization. In the presence of an
20 electric field, however, the permanent dipoles are forced to align along the field and the material will become distorted due to the asymmetric shape of the molecules. This leads to a macroscopic polarization in the material in the direction of the applied field.

25 In 1987 it was postulated by R.B.Meyer and J.S.Patel in Phys.Rev. Lett. 58 (15), 1538 (1987) that chiral nematic materials with a flexoelectric effect should exhibit fast electro-optic switching, which would make them interesting materials for liquid crystal displays and optical switches. Further work in this field is described e.g. by P.
30 Rudquist et al., Liq. Cryst. 23 (4), 503 (1997).

In a flexoelectric chiral nematic liquid crystal material with a helically twisted molecular orientation, application of an electric field perpendicular to the helix axis causes distortion to the molecular
35 directors, whereas the direction of the helical axis remains unchanged. This leads to a change in the optical properties of the

material, i.e. a tilt of the optical axis, relative to the helical axis, in the plane perpendicular to the direction of the applied field, as exemplarily depicted in Figure 1. The switching angle ϕ is defined as twice the tilt angle θ .

5

Figure 1, which is adapted from a diagram by J.S.Patel and S.-D.Lee, J. Appl. Phys. 66 (4) 1879 (1989), depicts the director and helix configuration in a flexoelectric cholesteric liquid crystalline material upon application of an electric field. Therein, h denotes the helix axis, O.A. denotes the optic axis, and E is the electric field, which is directed either into the plane of the drawing (indicated by \otimes) or out of the plane of the drawing (indicated by \odot).

10

The tilt of the optic axis causes a change in transmission of a sample of the flexoelectric material placed between crossed polarizers, which can be exploited in electrooptical applications.

15

However, the flexoelectric display devices and liquid crystal materials used therein that are known from prior art have several drawbacks. Thus, as it is often difficult to achieve uniform alignment over the entire active area of the display cell, previously only small areas could be aligned which required shearing of the cell.

20

Furthermore, when applying an electric field to the display, hitherto only moderate switching angles could be achieved at temperatures close to room temperature, whereas on the other hand high switching angles required high applied fields.

25

It was an aim of the invention to provide improved flexoelectric devices that exhibit high switching angles and fast response times. Another aim was to provide liquid crystal materials with advantageous properties, in particular for use in flexoelectric displays, that enable good uniform alignment over the entire area of the display cell without the use of a mechanical shearing process, good contrast, high switching angles and fast response times also at low temperatures. The liquid crystal materials should exhibit low

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melting points, broad chiral nematic phase ranges, short temperature independent pitch lengths and high flexoelectric coefficients. Other aims of the present invention are immediately evident to the person skilled in the art from the following detailed description.

5

The inventors have found out that the above aims can be achieved by providing bimesogenic compounds according to the present invention. These compounds, when used in chiral nematic liquid crystal mixtures, lead to low melting points, broad chiral nematic phases. In particular, they exhibit high values of the elastic constant K_{11} and the flexoelectric coefficient.

10

Apart from the use in flexoelectric devices, the inventive bimesogenic compounds as well as mixtures thereof are also suitable for other types of displays and other optical and electrooptical applications, such as optical compensation or polarizing films, colour filters, reflective cholesterics, optical rotatory power and optical information storage.

15

The inventors have also achieved several improvements in flexoelectric display devices that lead to improved electrooptical performance of these displays. Thus, it was found that by using a display cell comprising two transparent, plane parallel electrodes with hybrid alignment conditions, i.e. homeotropic alignment on the first electrode surface and planar alignment on the second electrode surface of the cell, improved flexoelectric switching performance of the display, in particular high switching angles, fast response times and good contrast can be achieved with stable alignment.

20

The term mesogenic compound as used in the foregoing and the following comprise compounds with a rod-shaped, board-shaped or disk-shaped mesogenic group, i.e. a group with the ability to induce mesophase behaviour in a compound comprising said group. These compounds do not necessarily have to exhibit mesophase behaviour themselves. Sometimes these compounds show mesophase behaviour only in mixtures with other compounds or, in case of

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polymerizable compounds, when these compounds or mixtures thereof are polymerized.

5 The term homeotropic alignment or orientation of a liquid crystal or mesogenic material in a display cell or on a substrate means that the mesogenic groups in the liquid crystal or mesogenic material are oriented substantially perpendicular to the plane of the cell or substrate, respectively.

10 The term planar alignment or orientation of a liquid crystal or mesogenic material in a display cell or on a substrate means that the mesogenic groups in the liquid crystal or mesogenic material are oriented substantially parallel to the plane of the cell or substrate, respectively.

15 The term hybrid alignment or orientation of a liquid crystal or mesogenic material in a display cell or between two substrates means that the mesogenic groups adjacent to the first cell wall or on the first substrate exhibit homeotropic orientation, and the mesogenic groups adjacent to the second cell wall or on the second substrate exhibit planar orientation.

20 One object of the present invention are bimesogenic compounds of formula I

25
$$R^1-MG^1-X^1-Sp-X^2-MG^2-R^2 \quad I$$

wherein

30 R^1 and R^2 are each independently F, Cl, CN, NCS or a straight-chain or branched alkyl group with 1 to 25 C atoms which may be unsubstituted, mono- or polysubstituted by halogen or CN, it being also possible for one or more non-adjacent CH_2 groups to be replaced, in each case
35 independently from one another, by -O-, -S-, -NH-, -N(CH_3)-, -CO-, -COO-, -OCO-, -O-CO-O-, -S-CO-, -CO-

S-, -CH=CH-, -CH=CF-, -CF=CF- or -C≡C- in such a manner that oxygen atoms are not linked directly to one another,

5 MG¹ and MG² are each independently a mesogenic group,

Sp is a spacer group comprising 5 to 40 C atoms, wherein one or more non-adjacent CH₂ groups may also be replaced by -O-, -S-, -NH-, -N(CH₃)-, -CO-, -O-CO-, -S-CO-, -O-COO-, -CO-S-, -CO-O-, -CH(halogen)-, -CH(CN)-, -CH=CH- or -C≡C-, and

10

X¹ and X² are each independently -O-, -S-, -CO-, -COO-, -OCO-, -O-CO-O-, -CO-NH-, -NH-CO-, -CH₂CH₂-, -OCH₂-, -CH₂O-, -SCH₂-, -CH₂S-, -CH=CH-, -CH=CH-COO-, -OCO-CH=CH-, -C≡C- or a single bond.

15

Another object of the invention is the use of bimesogenic compounds of formula I in liquid crystalline media and liquid crystal displays.

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Another object of the invention is a liquid crystalline medium comprising at least two components, at least one of which is a bimesogenic compound of formula I.

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Another object of the invention is a liquid crystal display with a liquid crystalline medium comprising at least two components, at least one of which is a bimesogenic compound of formula I.

Another object of the invention is a flexoelectric liquid crystal display with a liquid crystalline medium comprising at least two components, at least one of which is a bimesogenic compound of formula I.

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The mesogenic groups MG¹ and MG² are preferably selected of formula II

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wherein

- 5 Z^1 is in each case independently -COO-, -OCO-, -O-CO-O-,
 -OCH₂-, -CH₂O-, -CH₂CH₂-, -(CH₂)₄-, -CF₂CF₂-, -CH=CH-,
 -CF=CF-, -CH=CH-COO-, -OCO-CH=CH-, -C≡C- or a
 single bond,
- 10 A^1 and A^2 are each independently 1,4-phenylene, wherein in
 addition one or more CH groups may be replaced by N,
 trans-1,4-cyclohexylene in which, in addition, one or two
 non-adjacent CH₂ groups may be replaced by O and/or
 S, 1,4-cyclohexenylene, 1,4-bicyclo-(2,2,2)-octylene,
 15 piperidine-1,4-diyl, naphthalene-2,6-diyl, decahydro-
 naphthalene-2,6-diyl, 1,2,3,4-tetrahydro-naphthalene-
 2,6-diyl, cyclobutane-1,3-diyl, spiro[3.3]heptane-2,6-diyl
 or dispiro[3.1.3.1] decane-2,8-diyl, it being possible for
 all these groups to be unsubstituted, mono-, di-, tri- or
 20 tetrasubstituted with F, Cl, CN or alkyl, alkoxy,
 alkylcarbonyl or alkoxycarbonyl groups with 1 to 7 C
 atoms, wherein one or more H atoms may be substituted
 by F or Cl,
- 25 m is 0, 1, 2 or 3.

Especially preferred are compounds of formula I wherein R^1 -MG¹-X¹-
 and R^2 -MG²-X²- are identical.

30

Another preferred embodiment of the present invention relates to
 compounds of formula I wherein R^1 -MG¹-X¹- and R^2 -MG²-X²- are
 different.

35

Especially preferred are compounds of formula I wherein the mesogenic groups MG^1 and MG^2 comprise one, two or three six-membered rings.

- 5 A smaller group of preferred mesogenic groups of formula II is listed below. For reasons of simplicity, Phe in these groups is 1,4-phenylene, PheL is a 1,4-phenylene group which is substituted by 1 to 4 groups L, with L being F, Cl, CN, OH, NO_2 or an optionally fluorinated alkyl, alkoxy or alkanoyl group with 1 to 7 C atoms, and
10 Cyc is 1,4-cyclohexylene. This list is comprising the subformulae shown below as well as their mirror images

	-Phe-Z-Phe-	II-1
	-Phe-Z-Cyc-	II-2
15	-Cyc-Z-Cyc-	II-3
	-PheL-Z-Phe-	II-4
	-PheL-Z-Cyc-	II-5
	-PheL-Z-PheL-	II-6
	-Phe-Z-Phe-Z-Phe-	II-7
20	-Phe-Z-Phe-Z-Cyc-	II-8
	-Phe-Z-Cyc-Z-Phe-	II-9
	-Cyc-Z-Phe-Z-Cyc-	II-10
	-Phe-Z-Cyc-Z-Cyc-	II-11
	-Cyc-Z-Cyc-Z-Cyc-	II-12
25	-Phe-Z-Phe-Z-PheL-	II-13
	-Phe-Z-PheL-Z-Phe-	II-14
	-PheL-Z-Phe-Z-Phe-	II-15
	-PheL-Z-Phe-Z-PheL-	II-16
	-PheL-Z-PheL-Z-Phe-	II-17
30	-PheL-Z-PheL-Z-PheL-	II-18
	-Phe-Z-PheL-Z-Cyc-	II-19
	-Phe-Z-Cyc-Z-PheL-	II-20
	-Cyc-Z-Phe-Z-PheL-	II-21
	-PheL-Z-Cyc-Z-PheL-	II-22
35	-PheL-Z-PheL-Z-Cyc-	II-23
	-PheL-Z-Cyc-Z-Cyc-	II-24

-Cyc-Z-PheL-Z-Cyc-

II-25

Particularly preferred are the subformulae II-1, II-2, II-4, II-6, II-7, II-8, II-11, II-13, II-14, II-15 and II-16 .

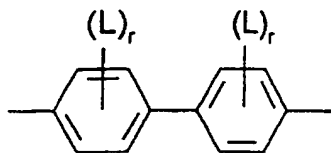
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In these preferred groups Z in each case independently has one of the meanings of Z^1 as given in formula I. Preferably Z is -COO-, -OCO-, -CH₂CH₂-, -C≡C- or a single bond.

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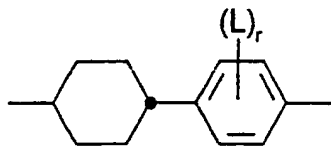
Very preferably the mesogenic groups MG^1 and MG^2 are selected from the following formulae and their mirror images

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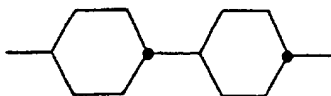


IIa

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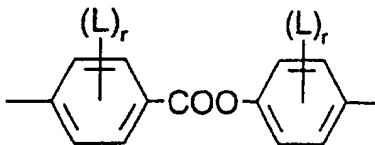


IIb



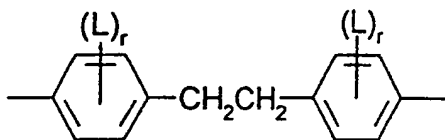
IIc

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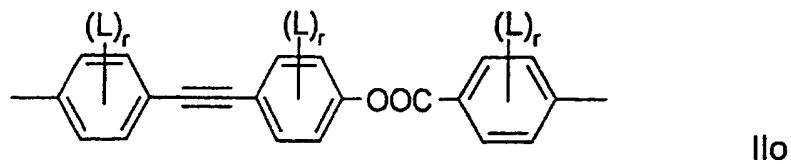
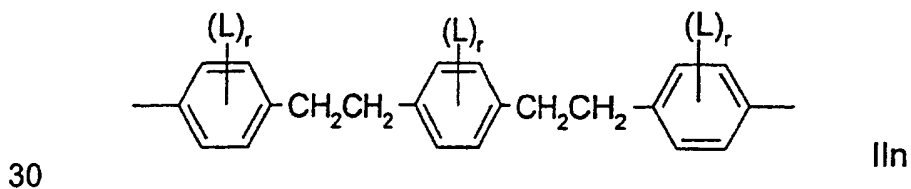
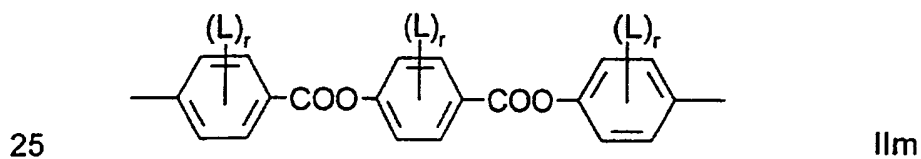
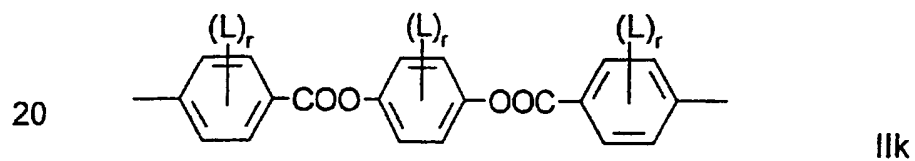
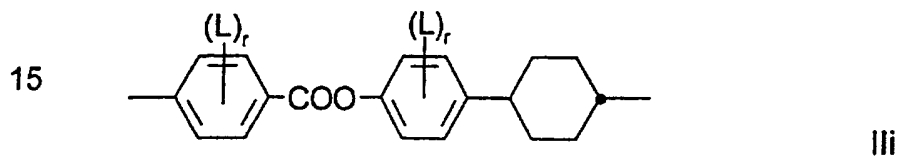
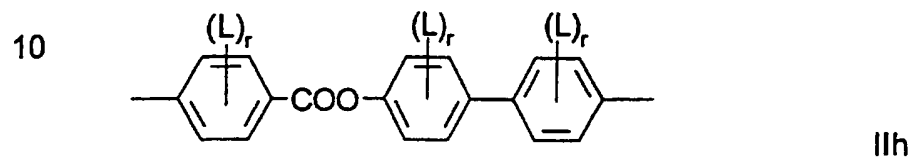
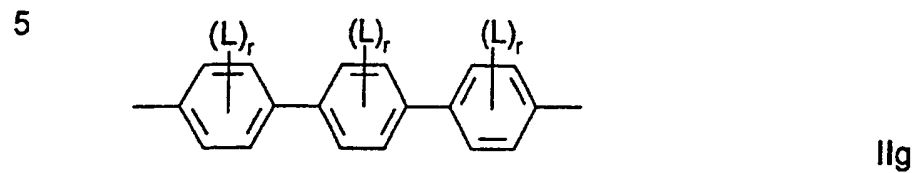
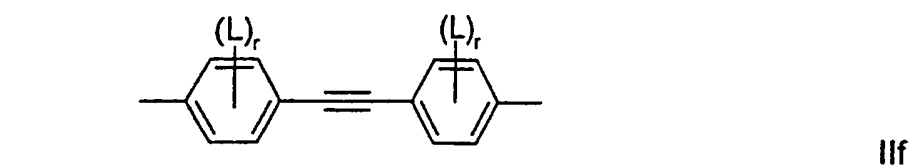
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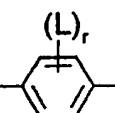
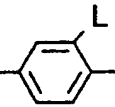
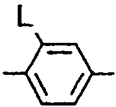
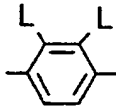
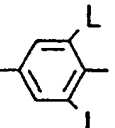


IIe

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wherein L has the meaning given above and r is 0, 1 or 2.

The group  in these preferred formulae is very preferably
 5 denoting ,  or , furthermore ,
 with L having each independently one of the meanings given above.

10 Particularly preferred are the subformulae IId, IIg, IIh, IIi, IIk and IIo,
 in particular the subformulae IId and IIk.

L is preferably F, Cl, CN, OH, NO₂, CH₃, C₂H₅, OCH₃, OC₂H₅,
 COCH₃, COC₂H₅, COOCH₃, COOC₂H₅, CF₃, OCF₃, OCHF₂, OC₂F₅,
 15 in particular F, Cl, CN, CH₃, C₂H₅, OCH₃, COCH₃ and OCF₃, most
 preferably F, Cl, CH₃, OCH₃ and COCH₃.

20 In case of a compounds with an unpolar polar group, R¹ and R² are
 preferably alkyl with up to 15 C atoms or alkoxy with 2 to 15 C atoms.

If R¹ or R² is an alkyl or alkoxy radical, i.e. where the terminal CH₂
 group is replaced by -O-, this may be straight-chain or branched. It is
 25 preferably straight-chain, has 2, 3, 4, 5, 6, 7 or 8 carbon atoms and
 accordingly is preferably ethyl, propyl, butyl, pentyl, hexyl, heptyl,
 octyl, ethoxy, propoxy, butoxy, pentoxy, hexoxy, heptoxy, or octoxy,
 furthermore methyl, nonyl, decyl, undecyl, dodecyl, tridecyl,
 tetradecyl, pentadecyl, nonoxy, decoxy, undecoxy, dodecoxy,
 30 tridecoxy or tetradecoxy, for example.

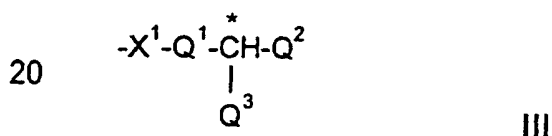
Oxaalkyl, i.e. where one CH₂ group is replaced by -O-, is preferably
 straight-chain 2-oxapropyl (=methoxymethyl), 2- (=ethoxymethyl) or
 3-oxabutyl (=2-methoxyethyl), 2-, 3-, or 4-oxapentyl, 2-, 3-, 4-, or 5-
 35 oxahexyl, 2-, 3-, 4-, 5-, or 6-oxaheptyl, 2-, 3-, 4-, 5-, 6- or 7-oxaoctyl,

2-, 3-, 4-, 5-, 6-, 7- or 8-oxanonyl or 2-, 3-, 4-, 5-, 6-, 7-, 8- or 9-oxadecyl, for example.

5 In case of a compounds with a terminal polar group, R^1 and R^2 are selected from CN, NO_2 , halogen, OCH_3 , OCN, SCN, COR^3 , $COOR^3$ or a mono- oligo- or polyfluorinated alkyl or alkoxy group with 1 to 4 C atoms. R^3 is optionally fluorinated alkyl with 1 to 4, preferably 1 to 3 C atoms. Halogen is preferably F or Cl.

10 Especially preferably R^1 and R^2 in formula I are selected of F, Cl, CN, NO_2 , OCH_3 , $COCH_3$, COC_2H_5 , $COOCH_3$, $COOC_2H_5$, CF_3 , C_2F_5 , OCF_3 , $OCHF_2$, and OC_2F_5 , in particular of F, Cl, CN, OCH_3 and OCF_3 .

15 In the compounds of formula I R^1 and R^2 may be a chiral or achiral group. In case of a chiral group they are preferably selected according to formula III



wherein

25 X^1 is -O-, -S-, -CO-, -COO-, -OCO-, -OCOO- or a single bond,

Q^1 is an alkylene or alkylene-oxy group with 1 to 10 C atoms or a single bond,

30 Q^2 is an alkyl or alkoxy group with 1 to 10 C atoms which may be unsubstituted, mono- or polysubstituted by halogen or CN, it being also possible for one or more non-adjacent CH_2 groups to be replaced, in each case independently from one another, by
 35 - $C\equiv C$ -, -O-, -S-, -NH-, -N(CH_3)-, -CO-, -COO-, -OCO-, -OCO-O-, -S-CO- or -CO-S- in such a manner that oxygen atoms are not linked directly to one another,

Q^3 is halogen, a cyano group or an alkyl or alkoxy group with 1 to 4 C atoms different from Q^2 .

- 5 In case Q^1 in formula III is an alkylene-oxy group, the O atom is preferably adjacent to the chiral C atom.

Preferred chiral groups R^1 and R^2 are 2-butyl (=1-methylpropyl), 2-methylbutyl, 2-methylpentyl, 3-methylpentyl, 2-ethylhexyl, 2-propylpentyl, 2-octyl, in particular 2-methylbutyl, 2-methylbutoxy, 2-methylpentoxy, 3-methylpentoxy, 2-ethylhexoxy, 1-methylhexoxy, 2-octyloxy, 2-oxa-3-methylbutyl, 3-oxa-4-methylpentyl, 4-methylhexyl, 2-nonyl, 2-decyl, 2-dodecyl, 6-methoxyoctoxy, 6-methyloctoxy, 6-methyloctanoyloxy, 5-methylheptyloxycarbonyl, 2-methylbutyryloxy, 3-methylvaleryloxy, 4-methylhexanoyloxy, 2-chloropropionyloxy, 2-chloro-3-methylbutyryloxy, 2-chloro-4-methylvaleryloxy, 2-chloro-3-methylvaleryloxy, 2-methyl-3-oxapentyl, 2-methyl-3-oxahexyl, 1-methoxypropyl-2-oxy, 1-ethoxypropyl-2-oxy, 1-propoxypropyl-2-oxy, 1-butoxypropyl-2-oxy, 2-fluorooctyloxy, 2-fluorodecyloxy for example.

20

In addition, compounds of formula I containing an achiral branched group R^1 and/or R^2 may occasionally be of importance, for example, due to a reduction in the tendency towards crystallization. Branched groups of this type generally do not contain more than one chain branch. Preferred achiral branched groups are isopropyl, isobutyl (=methylpropyl), isopentyl (=3-methylbutyl), isopropoxy, 2-methylpropoxy and 3-methylbutoxy.

25

As for the spacer group Sp in formula I all groups can be used that are known for this purpose to the skilled in the art. The spacer group Sp is preferably a linear or branched alkylene group having 5 to 40 C atoms, in particular 5 to 25 C atoms, very preferably 5 to 15 C atoms, in which, in addition, one or more non-adjacent CH_2 groups may be replaced by -O-, -S-, -NH-, -N(CH₃)-, -CO-, -O-CO-, -S-CO-, -O-COO-, -CO-S-, -CO-O-, -CH(halogen)-, -CH(CN)-, -CH=CH- or -C≡C-.

35

Typical spacer groups are for example $-(CH_2)_o-$, $-(CH_2CH_2O)_p-CH_2CH_2-$, $-CH_2CH_2-S-CH_2CH_2-$ or $-CH_2CH_2-NH-CH_2CH_2-$, with o being an integer from 5 to 40, in particular from 5 to 25, very preferably from 5 to 15, and p being an integer from 1 to 8, in particular 1, 2, 3 or 4.

5

Preferred spacer groups are pentylene, hexylene, heptylene, octylene, nonylene, decylene, undecylene, dodecylene, octadecylene, diethyleneoxyethylene, dimethyleneoxybutylene, pentenyylene, heptenyylene, nonenyylene and undecenylene, for example.

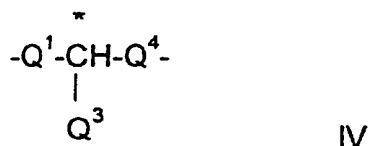
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Especially preferred are inventive compounds of formula I wherein Sp is denoting alkylene with 5 to 15 C atoms. Straight-chain alkylene groups are especially preferred.

15

In another preferred embodiment of the invention the chiral compounds of formula I comprise at least one spacer group Sp that is a chiral group of the formula IV:

20



wherein

25

Q^1 is an alkylene or alkylene-oxy group with 1 to 16 C atoms or a single bond,

30

Q^2 is an alkyl or alkoxy group with 2 to 16 C atoms which may be unsubstituted, mono- or polysubstituted by halogen or CN, it being also possible for one or more non-adjacent CH_2 groups to be replaced, in each case independently from one another, by $-C\equiv C-$, $-O-$, $-S-$, $-NH-$, $-N(CH_3)-$, $-CO-$, $-COO-$, $-OCO-$, $-OCO-O-$, $-S-CO-$ or $-CO-S-$ in such a manner that oxygen atoms are not linked directly to one another,

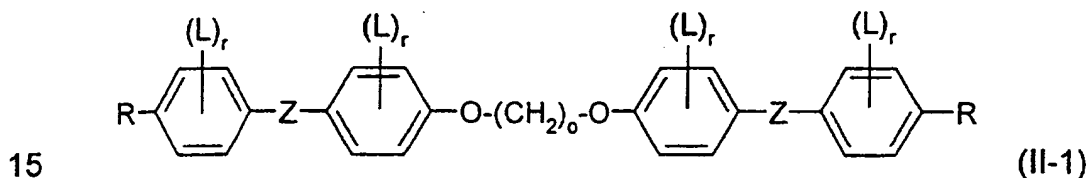
35

Q^3 is halogen, a cyano group or an alkyl or alkoxy group with 1 to 7 C atoms different from Q^2 .

5 In case Q^1 in formula III is an alkylene-oxy group, the O atom is preferably adjacent to the chiral C atom.

X^1 and X^2 in formula I denote preferably -O-, -CO-, -COO-, -OCO-, -O-CO-O- or a single bond.

10 Particularly preferred are the following compounds



wherein R has one of the meanings of R^1 , Z has one of the meanings of Z^1 and o, L and r are as defined above, including the preferred meanings of these groups.

20

The compounds of formula I can be synthesized according to or in analogy to methods which are known per se and which are described in standard works of organic chemistry such as, for example, Houben-Weyl, Methoden der organischen Chemie, Thieme-Verlag, Stuttgart. Some specific methods of preparation can be taken from the examples.

25

30 Another object of the present invention is a liquid crystalline medium comprising at least one compound of formula I.

In a preferred embodiment of the invention the liquid crystalline medium is consisting of 2 to 25, preferably 3 to 15 compounds, at least one of which is a compound of formula I.

35

The liquid crystalline mixture according to the invention preferably comprises 1 to 5, very preferably 1, 2 or 3 compounds of formula I.

5 The other compounds are preferably low molecular weight liquid crystalline co-components selected from nematic or nematogenic substances, for example from the known classes of the azoxybenzenes, benzylidene-anilines, biphenyls, terphenyls, phenyl or cyclohexyl benzoates, phenyl or cyclohexyl esters of cyclohexanecarboxylic acid, phenyl or cyclohexyl esters of
10 cyclohexylbenzoic acid, phenyl or cyclohexyl esters of cyclohexylcyclohexanecarboxylic acid, cyclohexylphenyl esters of benzoic acid, of cyclohexanecarboxylic acid and of cyclohexylcyclohexanecarboxylic acid, phenylcyclohexanes, cyclohexylbiphenyls, phenylcyclohexylcyclohexanes, cyclohexylcyclohexanes, cyclohexylcyclohexenes, cyclohexylcyclohexylcyclohexenes, 1,4-bis-
15 cyclohexylbenzenes, 4,4'-bis-cyclohexylbiphenyls, phenyl- or cyclohexylpyrimidines, phenyl- or cyclohexylpyridines, phenyl- or cyclohexylpyridazines, phenyl- or cyclohexyldioxanes, phenyl- or cyclohexyl-1,3-dithianes, 1,2-diphenyl-ethanes, 1,2-dicyclohexylethanes, 1-phenyl-2-cyclohexylethanes, 1-cyclohexyl-2-(4-phenylcyclohexyl)-
20 ethanes, 1-cyclohexyl-2-biphenyl-ethanes, 1-phenyl-2-cyclohexylphenylethanes, optionally halogenated stilbenes, benzyl phenyl ether, tolanes, substituted cinnamic acids and further classes of nematic or nematogenic substances. The 1,4-phenylene groups in
25 these compounds may also be laterally mono- or difluorinated.

The liquid crystalline mixture of this preferred embodiment is based on the achiral compounds of this type.

30 The most important compounds that are possible as components of these liquid crystalline mixtures can be characterized by the following formula



35

wherein L' and E, which may be identical or different, are in each case, independently from one another, a bivalent radical from the group formed by -Phe-, -Cyc-, -Phe-Phe-, -Phe-Cyc-, -Cyc-Cyc-, -Pyr-, -Dio-, -B-Phe- and -B-Cyc- and their mirror images, where Phe is unsubstituted or fluorine-substituted 1,4-phenylene, Cyc is trans-1,4-cyclohexylene or 1,4-cyclohexenylene, Pyr is pyrimidine-2,5-diyl or pyridine-2,5-diyl, Dio is 1,3-dioxane-2,5-diyl and B is 2-(trans-1,4-cyclohexyl)ethyl, pyrimidine-2,5-diyl, pyridine-2,5-diyl or 1,3-dioxane-2,5-diyl.

G' in these compounds is selected from the following bivalent groups -CH=CH-, -N(O)N-, -CH=CY-, -CH=N(O)-, -C≡C-, -CH₂-CH₂-, -CO-O-, -CH₂-O-, -CO-S-, -CH₂-S-, -CH=N-, -COO-Phe-COO- or a single bond, with Y being halogen, preferably chlorine, or -CN.

R' and R'' are, in each case, independently of one another, alkyl, alkenyl, alkoxy, alkenyloxy, alkanoyloxy, alkoxycarbonyl or alkoxycarbonyloxy with 1 to 18, preferably 3 to 12 C atoms, or alternatively one of R' and R'' is F, CF₃, OCF₃, Cl, NCS or CN.

In most of these compounds R' and R'' are, in each case, independently of each another, alkyl, alkenyl or alkoxy with different chain length, wherein the sum of C atoms in nematic media generally is between 2 and 9, preferably between 2 and 7.

Many of these compounds or mixtures thereof are commercially available. All of these compounds are either known or can be prepared by methods which are known per se, as described in the literature (for example in the standard works such as Houben-Weyl, Methoden der Organischen Chemie [Methods of Organic Chemistry], Georg-Thieme-Verlag, Stuttgart), to be precise under reaction conditions which are known and suitable for said reactions. Use may also be made here of variants which are known per se, but are not mentioned here.

The liquid crystalline medium according to this preferred embodiment comprises preferably 5 to 90 %, in particular 10 to 75 %, very preferably 15 to 60 % by weight of one or more compounds of formula I.

5

In another preferred embodiment of the present invention, the liquid crystal medium essentially consists of bimesogenic compounds of formula I.

10

To induce a helical twist in the liquid crystalline medium that is needed in case of flexoelectric displays, preferably one or more chiral dopants are added to the medium.

15

In addition or alternatively to the chiral dopants it is also possible to use one or more bimesogenic compounds with a chiral group, or one or more co-components as described above with a chiral group.

20

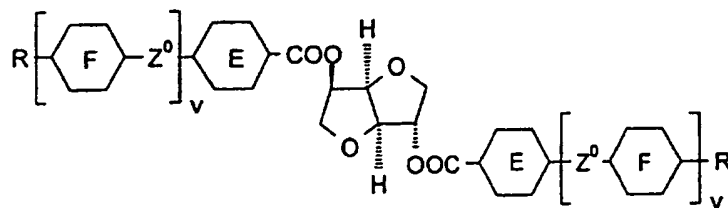
A liquid crystalline medium according to the preferred embodiments as described above comprises one or more chiral dopants which themselves do not necessarily have to show a liquid crystalline phase and give good uniform alignment themselves.

25

Especially preferred are chiral dopants with a high helical twisting power (HTP), in particular those disclosed in WO 98/00428. Further typically used chiral dopants are e.g. the commercially available S 1011, R 811 or CB 15 (from Merck KGaA, Darmstadt, Germany).

Especially preferred are chiral dopants selected from formula VII

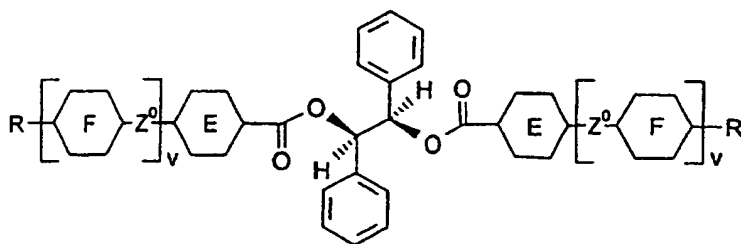
30



VII

35

and formula VIII



VIII

including the respective (S,S) enantiomer,

wherein E and F are each independently 1,4-phenylene or trans-1,4-cyclohexylene, v is 0 or 1, Z⁰ is -COO-, -OCO-, -CH₂CH₂- or a single bond, and R is alkyl, alkoxy or alkanoyl with 1 to 12 C atoms.

The compounds of formula VII and their synthesis are described in WO 98/00428. The compounds of formula VIII and their synthesis are described in GB 2,328,207.

The above chiral compounds of formula VII and VIII exhibit a very high helical twisting power (HTP), and are therefore particularly useful for the purpose of the present invention.

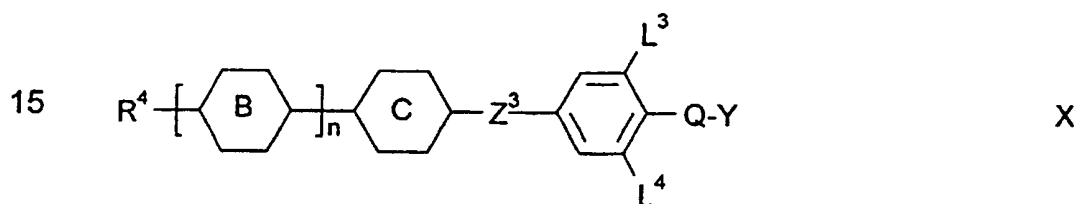
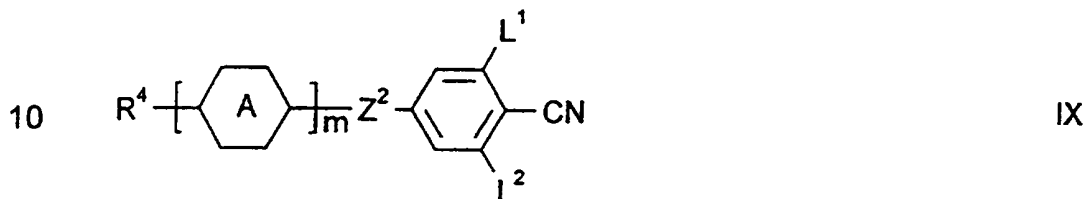
The liquid crystalline medium preferably comprises preferably 1 to 5, in particular 1 to 3, very preferably 1 or 2 chiral dopants.

The amount of chiral dopants in the liquid crystalline medium is preferably from 0.1 to 15 %, in particular from 0.3 to 10 %, very preferably 0.5 to 8 % by weight of the total mixture.

A medium comprising more than one, in particular 2, 3 or 4 dopants, preferably selected from the above formulae VII and VIII, is particularly preferred, as thereby crystallization of the dopant is suppressed.

Further preferred are liquid crystalline media comprising one or more additives selected from low viscosity additives, additives with a high positive $\Delta\epsilon$ and high clearing point additives.

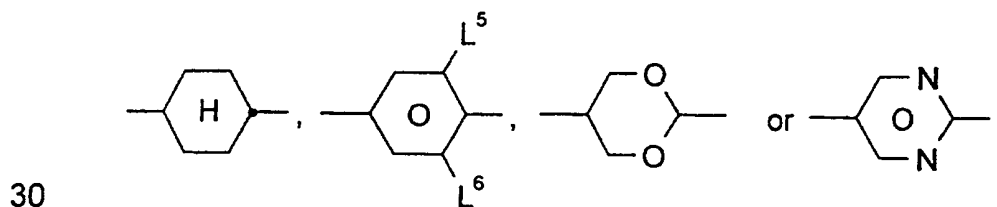
- 5 Suitable high $\Delta\epsilon$ additives are e.g. mesogenic or liquid crystalline compounds selected from the following formulae



wherein

20 R^4 is alkyl, alkoxy, alkenyl or alkenyloxy with up to 12 C atoms,

25 A , B and C are each independently



L^1 through L^6 are each independently H or F,

35 Z^2 is $-\text{COO}-$, $-\text{CH}_2\text{CH}_2-$ or a single bond,

Z^3 is $-\text{COO}-$, $-\text{CH}_2\text{CH}_2-$, $-\text{C}\equiv\text{C}-$ or a single bond,

Q is CF_2 , OCF_2 , CFH , OCFH or a single bond,

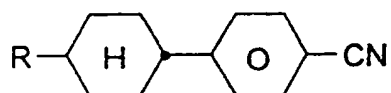
Y is F or Cl,

5

m is 1 or 2, and

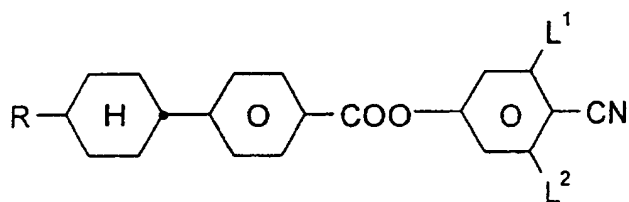
n is 0 or 1.

10 Particularly preferred high $\Delta\epsilon$ compounds of formula IX and X are selected from the following formulae



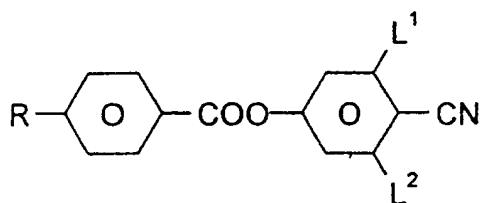
IXa

15



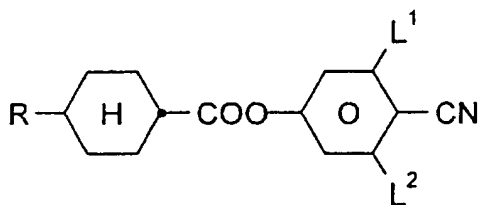
IXb

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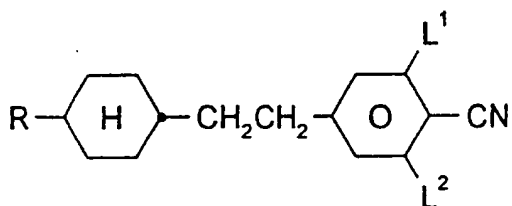
IXc

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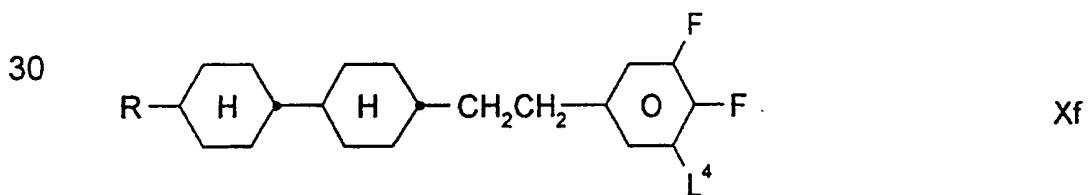
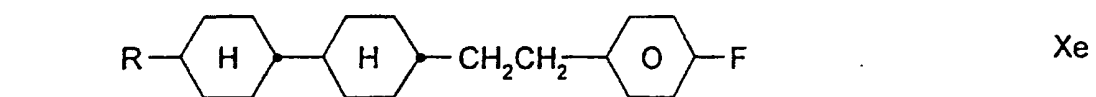
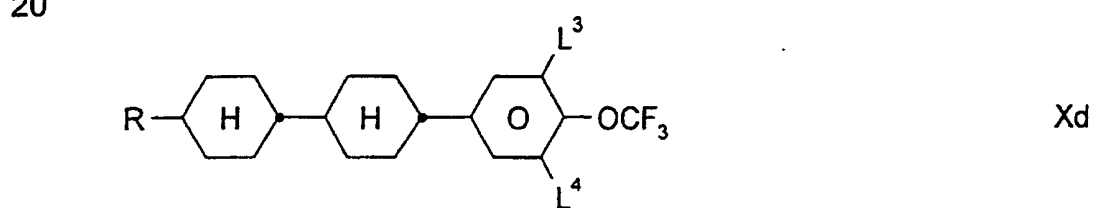
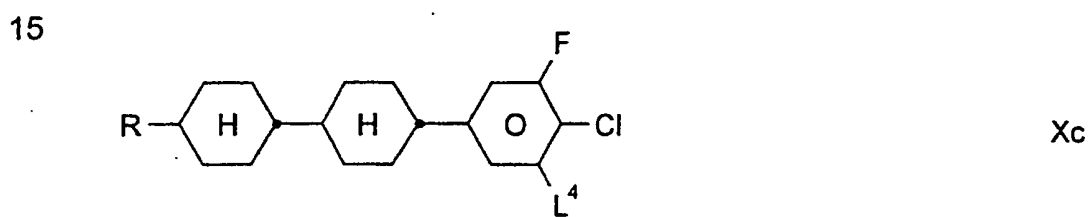
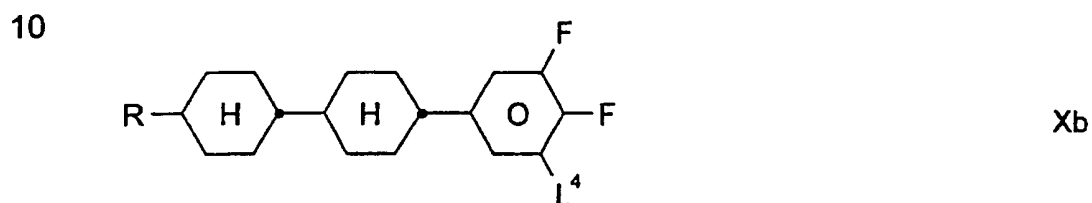
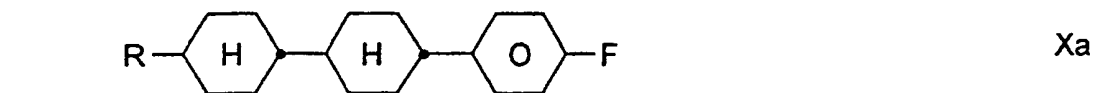
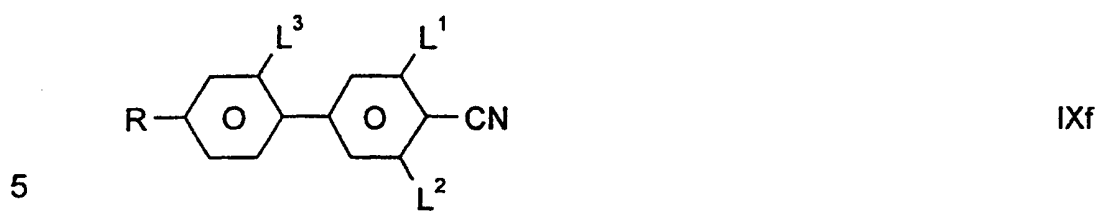
IXd

30

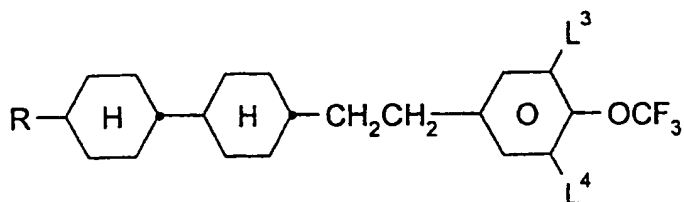


IXe

35

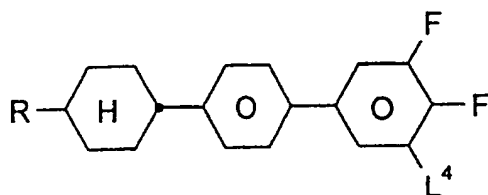


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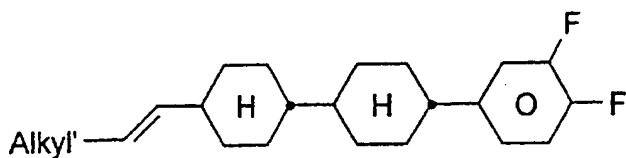
Xg

10



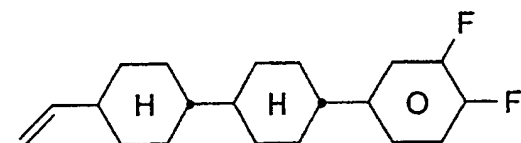
Xh

15



Xi

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Xj

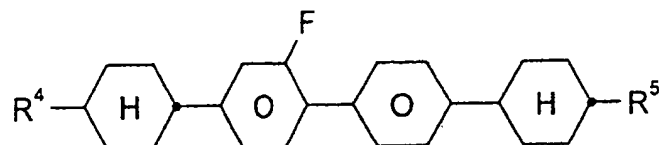
wherein Alkyl is H or an alkyl group with 1 to 5 C atoms, R has one of the meanings of R⁴ above and L¹, L², L³ and L⁴ have the above meanings.

25

Suitable high clearing point additives are e.g. mesogenic or liquid crystalline compounds comprising four six membered ring groups.

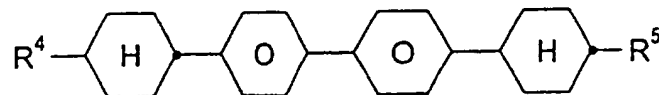
Particularly preferred high clearing point compounds are selected from the following formulae

30

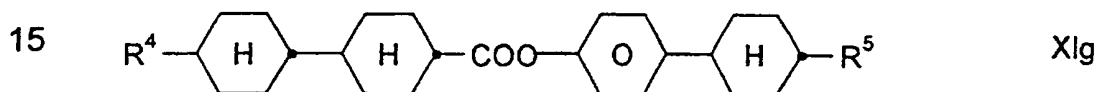
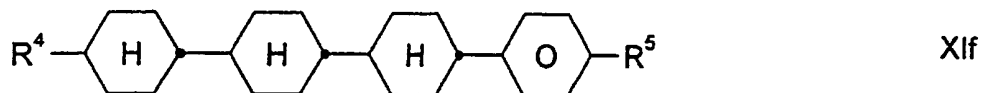
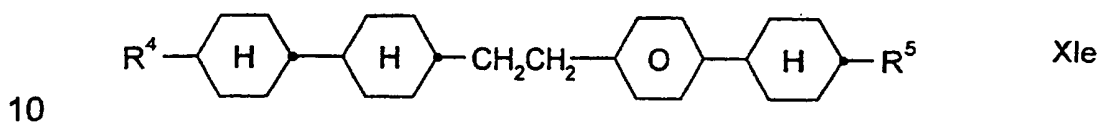
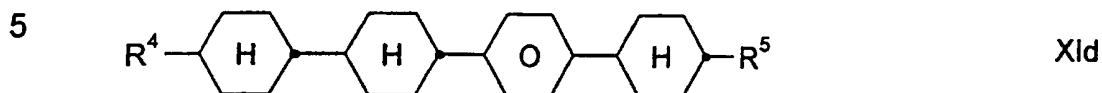
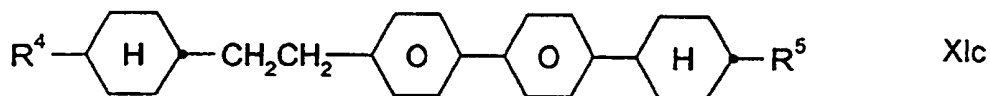


Xla

35



Xlb



20 in which R⁵ has one of the meanings of R⁴ and the 1,4-phenylene groups in Xla to Xle may each, independently of one another, also be mono- or polysubstituted by fluorine.

25 Suitable low viscosity additives are e.g. mesogenic or liquid crystalline compounds selected from the class of cyclohexyl-cyclohexylenes with unpolar terminal groups.

Preferably the low viscosity compounds are selected from formula XII



30

wherein R⁶ and R⁷ have one of the meanings of R⁴ in formula IX.

35 Particularly preferred are compounds of formula XII wherein R⁶ and/or R⁷ are alkenyl, preferably 1 E-alkenyl or 3 E-alkenyl with 2 to 7 C atoms.

5 The bimesogenic compounds of formula I and the liquid crystalline media comprising them can be used in liquid crystal displays, such as STN, TN, AMD-TN, temperature compensation, guest-host, phase change or surface stabilized or polymer stabilized cholesteric texture (SSCT, PSCT) displays, in particular in flexoelectric devices, in active and passive optical elements like polarizers, compensators, reflectors, alignment layers, colour filters or holographic elements, in adhesives, synthetic resins with anisotropic mechanical properties, cosmetics, diagnostics, liquid crystal pigments, for decorative and security applications, in nonlinear optics, optical information storage or as chiral dopants.

15 The compounds of formula I, and the mixtures obtainable thereof are particularly useful for flexoelectric liquid crystal display. Thus, another object of the present invention is a flexoelectric display comprising one or more compounds of formula I, or comprising a liquid crystal medium comprising at least one compound of formula I.

20 The inventive bimesogenic compounds of formula I and the mixtures thereof can be aligned in their cholesteric phase into different states of orientation by methods that are known to the expert, such as surface treatment or electric fields. For example, they can be aligned into the planar (Grandjean) state, into the focal conic state or into the homeotropic state. Inventive compounds of formula I comprising polar groups with a strong dipole moment can further be subjected to flexoelectric switching, and can thus be used in electrooptical switches or liquid crystal displays.

30 The switching between different states of orientation according to a preferred embodiment of the present invention is exemplarily described below in detail for a sample of an inventive compound of formula I.

35 According to this preferred embodiment, the sample is placed into a cell comprising two plane-parallel glass plates coated with electrode layers, e.g. ITO layers, and aligned in its cholesteric phase into a

planar state wherein the axis of the cholesteric helix is oriented normal to the cell walls. This state is also known as Grandjean state, and the texture of the sample, which is observable e.g. in a polarization microscope, as Grandjean texture. Planar alignment can be achieved
5 e.g. by surface treatment of the cell walls, for example by rubbing and/or coating with an alignment layer such as polyimide.

A Grandjean state with a high quality of alignment and only few defects can further be achieved by heating the sample to the
10 isotropic phase, subsequently cooling to the chiral nematic phase at a temperature close to the chiral nematic-isotropic phase transition, and rubbing the cell.

In the planar state, the sample shows selective reflection of incident
15 light, with the central wavelength of reflection depending on the helical pitch and the mean refractive index of the material.

When an electric field is applied to the electrodes, for example with a frequency from 10 Hz to 1 kHz, and an amplitude of up to $12 V_{\text{rms}} / \mu\text{m}$,
20 the sample is being switched into a homeotropic state where the helix is unwound and the molecules are oriented parallel to the field, i.e. normal to the plane of the electrodes. In the homeotropic state, the sample is transmissive when viewed in normal daylight, and appears black when being put between crossed polarizers.

25 Upon reduction or removal of the electric field in the homeotropic state, the sample adopts a focal conic texture, where the molecules exhibit a helically twisted structure with the helical axis being oriented perpendicular to the field, i.e. parallel to the plane of the electrodes.

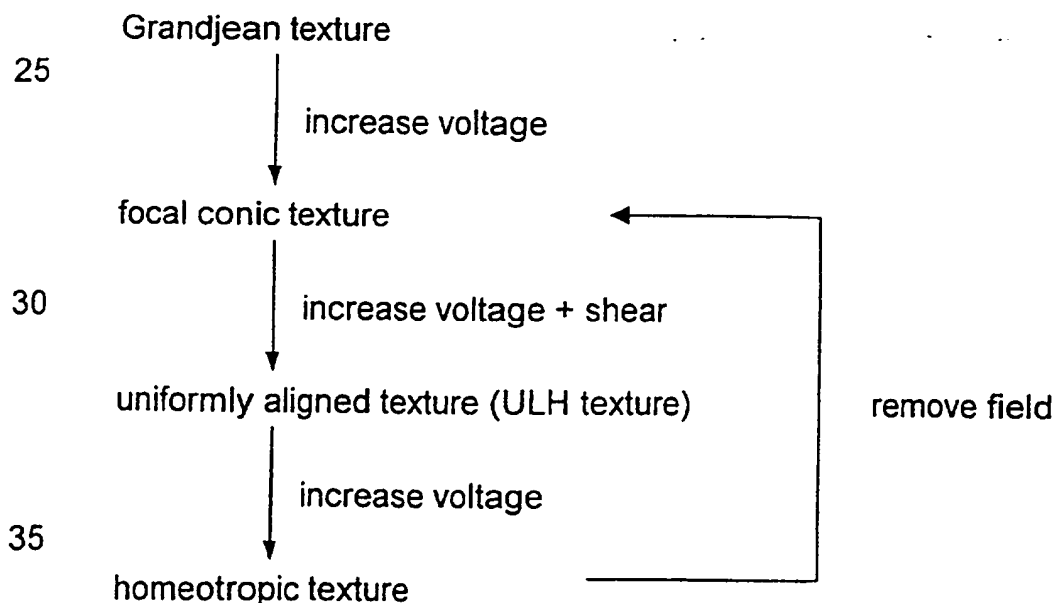
30 A focal conic state can also be achieved by applying only a weak electric field to a sample in its planar state. In the focal conic state the sample is scattering when viewed in normal daylight and appears bright between crossed polarizers.

35 A sample of an inventive compound in the different states of orientation exhibits different transmission of light. Therefore, the

respective state of orientation, as well as its quality of alignment, can be controlled by measuring the light transmission of the sample depending on the strength of the applied electric field. Thereby it is also possible to determine the electric field strength required to achieve specific states of orientation and transitions between these different states.

In a sample of an inventive compound of formula I, the above described focal conic state consists of many disordered birefringent small domains. By applying an electric field greater than the field for nucleation of the focal conic texture, preferably with additional shearing of the cell, a uniformly aligned texture is achieved where the helical axis is parallel to the plane of the electrodes in large, well-aligned areas. In accordance with the literature on state of the art chiral nematic materials, such as P. Rudquist et al., *Liq. Cryst.* **23** (4), 503 (1997), this texture is also called uniformly-lying helix (ULH) texture. This texture is required to characterize the flexoelectric properties of the inventive compound.

The sequence of textures typically observed in a sample of an inventive compound of formula I on a rubbed polyimide substrate upon increasing or decreasing electric field is given below:



Starting from the ULH texture, the inventive flexoelectric compounds and mixtures can be subjected to flexoelectric switching by application of an electric field. This causes rotation of the optic axis of the material in the plane of the cell substrates, as shown in Figure 1, which leads to a change in transmission when placing the material between crossed polarizers. The flexoelectric switching of inventive materials is further described in detail in the introduction above and in the examples.

It is also possible to obtain the ULH texture, starting from the focal conic texture, by applying an electric field with a high frequency, of for example 10 kHz, to the sample whilst cooling slowly from the isotropic phase into the cholesteric phase and shearing the cell. The field frequency may differ for different compounds.

The bimesogenic compounds of formula I are particularly useful in flexoelectric liquid crystal displays as they can easily be aligned into macroscopically uniform orientation, and lead to high values of the elastic constant K_{11} and a high flexoelectric coefficient e in the liquid crystal medium.

The liquid crystal medium preferably exhibits a $K_{11} > 1 \times 10^{-10}$ N and a flexoelectric coefficient $e > 1 \times 10^{-10}$ C/m.

A further aspect of the present invention relates to improvements in flexoelectric devices. In particular, the inventors have found that by using a display cell wherein the cell walls exhibit hybrid alignment conditions, a flexoelectric display device with improved electrooptical performance can be realized.

Thus, a flexoelectric display according to a preferred embodiment of the present invention comprises two plane parallel substrates, preferably glass plates covered with a transparent conductive layer such as indium tin oxide (ITO) on their inner surfaces, and a flexoelectric liquid crystalline medium provided between the substrates, characterized in that one of the inner substrate surfaces

exhibits homeotropic alignment conditions and the opposite inner substrate surface exhibits planar alignment conditions for the liquid crystalline medium.

- 5 Planar alignment can be achieved e.g. by means of an alignment layer, for example a layer of rubbed polyimide or sputtered SiO_x , that is applied on top of the substrate.

- 10 Alternatively it is possible to directly rub the substrate, i.e. without applying an additional alignment layer. For example rubbing can be achieved by means of a rubbing cloth, such as a velvet cloth, or with a flat bar coated with a rubbing cloth. In a preferred embodiment of the present invention rubbing is achieved by means of a at least one rubbing roller, like e.g. a fast spinning roller that is brushing across
15 the substrate, or by putting the substrate between at least two rollers, wherein in each case at least one of the rollers is optionally covered with a rubbing cloth. In another preferred embodiment of the present invention rubbing is achieved by wrapping the substrate at least partially at a defined angle around a roller that is preferably coated
20 with a rubbing cloth.

- Homeotropic alignment can be achieved e.g. by means of an alignment layer coated on top of the substrate. Suitable aligning agents used on glass substrates are for example alkyltrichlorosilane
25 or lecithine, whereas for a plastic substrate thin layers of lecithine, silica or high tilt polyimide orientation films as aligning agents may be used. In a preferred embodiment of the invention a silica coated plastic film is used as a substrate.

- 30 Further suitable methods to achieve planar or homeotropic alignment are described for example in J. Cognard, Mol.Cryst.Liq.Cryst. 78, Supplement 1, 1-77 (1981).

- 35 By using a display cell with hybrid alignment conditions, a very high switching angle of flexoelectric switching, fast response times and a good contrast can be achieved.

5 The flexoelectric display according to present invention may also comprise plastic substrates instead of glass substrates. Plastic film substrates are particularly suitable for rubbing treatment by rubbing rollers as described above.

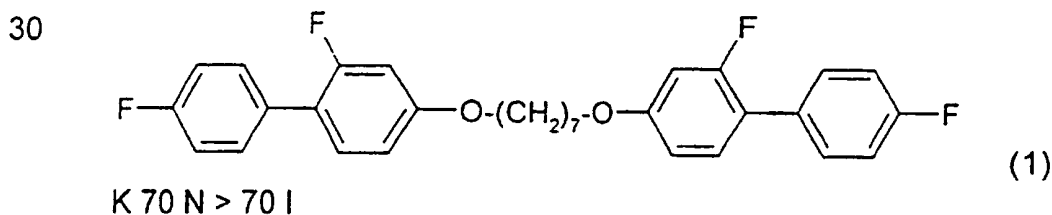
10 Without further elaboration, it is believed that one skilled in the art can, using the preceding description, utilize the present invention to its fullest extent. The following examples are, therefore, to be construed as merely illustrative and not limitative of the remainder of the disclosure in any way whatsoever.

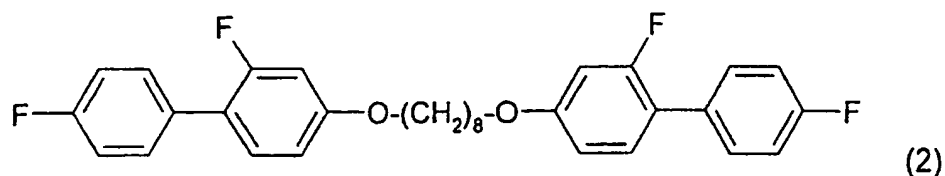
15 In the foregoing and in the following examples, unless otherwise indicated, all temperatures are set forth uncorrected in degrees Celsius and all parts and percentages are by weight.

20 The following abbreviations are used to illustrate the liquid crystalline phase behaviour of the compounds: K = crystalline; N = nematic; S = smectic; Ch = cholesteric; I = isotropic. The numbers between the symbols indicate the phase transition temperatures in ° C.

Example 1

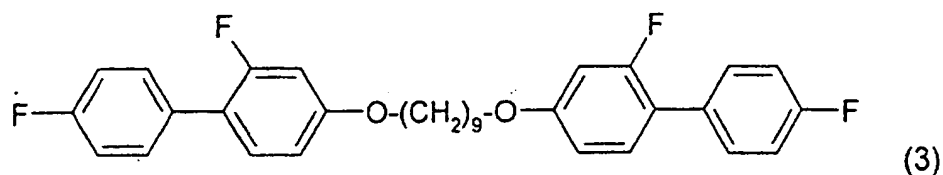
25 The compounds of formula (1), (2) and (3) were prepared by reacting the corresponding dibromoalkane $\text{Br}-(\text{CH}_2)_o-\text{Br}$, wherein o is 7, 8 or 9, with 2-fluoro-4'-fluorobiphenol according to conventional methods. The compounds (1)-(3) exhibit monotropic nematic phases.





5

K 125.5 N 100.9 I



10

K 66.5 N 61.3 I

Example 2

15

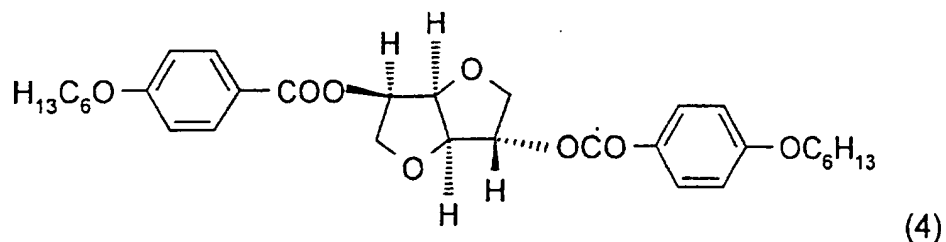
The nematic liquid crystal mixture (A) was formulated comprising 50 % by weight of each compound (1) and compound (3) of example 1.

Mixture (A) has the phase behaviour N 53 I.

20

The cholesteric mixture (B) was prepared by adding 4 % by weight of chiral dopant (4) to nematic mixture A.

25



30

The synthesis of dopant (4) is described in WO 98/00428.

Mixture (B) exhibits the phase behaviour Ch 48 I and shows selective reflection of deep blue light.

35

Cholesteric mixture (B) was filled into a cell comprising two transparent glass plates, the inner surfaces of which were covered

with conductive ITO layers as electrodes and spaced apart at a distance of 4.96 μm . One of the electrode surfaces was treated to induce planar alignment and the opposite electrode surface was treated to induce homeotropic alignment.

5

The filled cell was heated to the isotropic phase and slowly cooled at 0.5 $^{\circ}\text{C}/\text{min}$ while a field of 18 $\text{V}_{\text{pp}}\mu\text{m}^{-1}$ and 80 Hz was applied. As a result the liquid crystal mixture in the cell exhibited an ULH texture with uniform alignment over the active area (i.e. including the entire electrode area) of the display cell.

10

At a field of 55 $\text{V}_{\text{pp}}\mu\text{m}^{-1}$, which is called the 'critical field', the cholesteric helix was unwound.

15

The cell was subjected to flexoelectric switching as follows:

Square wave electric fields of 80 Hz frequency and different amplitude were applied to the sample, thus the material was subjected to an alternately-poled DC field of 6.25 ms duration.

20

The field was lower than the critical field so that the mixture was in the ULH texture.

25

The electric field caused flexoelectric switching in the compound 1a, with the optic axis of the material being tilted at an angle relative to the plane of the layer. The switching angle ϕ was evaluated by holding the sample between crossed polarizers and measuring the angle between the two extinction positions.

30

The response time for a change from 10 to 90 % of transmsion measured at 22 $\text{V}_{\text{pp}}\mu\text{m}^{-1}$ was 688 microseconds. The switching angle ϕ increased with increasing voltage, as shown in the table below.

35

Switching Angle ϕ (°)	Voltage $V_{pp} \mu m^{-1}$
66	30
90	52
97	54

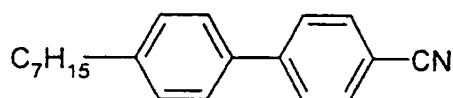
5

The elastic constant K_{11} was calculated for nematic mixture (A) from the Fredericks splay threshold voltage, which was measured as 49 V at 30 °C, and the dielectric anisotropy of mixture (A). This gave a value of K_{11} of mixture (A) of about 2.154×10^{-9} N, which is very high.

10

In comparison, for example the commercially available liquid crystal compound 7CB (from Merck KGaA, Darmstadt, Germany) of formula

15



20

has a value of K_{11} of about 14.1×10^{-12} N, which is more than two orders of magnitude smaller than that of mixture (A).

The flexoelectric coefficient e of mixture (A) was calculated from the following equation

25

$$(\tan \theta) / E = (p / 2\pi) (e / K)$$

wherein θ is the tilt angle ($\phi = 2\theta$), E is the electric field, p is the pitch of the cholesteric helix and K is the elastic constant (in this case K_{11}).

30

This gave a value for e of mixture (A) of about 1.39×10^{-9} , which is very high.

35

For example, the commercially available liquid crystal compound 7CB has a value of e of 10.78×10^{-12} , which is more than two orders of magnitude smaller than that of mixture (A).

5 The preceding examples can be repeated with similar success by substituting the generically or specifically described reactants and/or operating conditions of this invention for those used in the preceding examples.

10 From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention, and without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various conditions and usages.

15

20

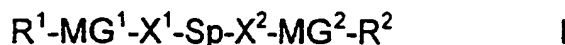
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30

35

Claims

1. A bimesogenic compound of formula I



wherein

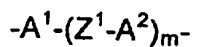
R^1 and R^2 are each independently F, Cl, CN, NCS or a straight-chain or branched alkyl group with 1 to 25 C atoms which may be unsubstituted, mono- or polysubstituted by halogen or CN, it being also possible for one or more non-adjacent CH_2 groups to be replaced, in each case independently from one another, by -O-, -S-, -NH-, -N(CH₃)-, -CO-, -COO-, -OCO-, -O-CO-O-, -S-CO-, -CO-S-, -CH=CH-, -CH=CF-, -CF=CF- or -C≡C- in such a manner that oxygen atoms are not linked directly to one another,

MG^1 and MG^2 are each independently a mesogenic group,

Sp is a spacer group comprising comprising 5 to 40 C atoms, wherein one or more non-adjacent CH_2 groups may also be replaced by -O-, -S-, -NH-, -N(CH₃)-, -CO-, -O-CO-, -S-CO-, -O-COO-, -CO-S-, -CO-O-, -CH(halogen)-, -CH(CN)-, -CH=CH- or -C≡C-,

X^1 and X^2 are each independently -O-, -S-, -CO-, -COO-, -OCO-, -O-CO-O-, -CO-NH-, -NH-CO-, -CH₂CH₂-, -OCH₂-, -CH₂O-, -SCH₂-, -CH₂S-, -CH=CH-, -CH=CH-COO-, -OCO-CH=CH-, -C≡C- or a single bond.

2. A bisomesogenic compound as claimed in claim 1, characterized in that MG^1 and MG^2 are compounds of formula II



II

wherein

Z^1

is in each case independently $-COO-$, $-OCO-$, $-O-CO-O-$, $-OCH_2-$, $-CH_2O-$, $-CH_2CH_2-$, $-(CH_2)_4-$, $-CF_2CF_2-$, $-CH=CH-$, $-CF=CF-$, $-CH=CH-COO-$, $-OCO-CH=CH-$, $-C\equiv C-$ or a single bond,

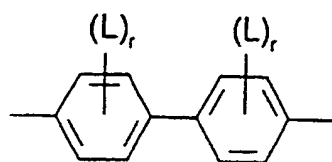
A^1 and A^2

are each independently 1,4-phenylene, wherein in addition one or more CH groups may be replaced by N, trans-1,4-cyclohexylene in which, in addition, one or two non-adjacent CH_2 groups may be replaced by O and/or S, 1,4-cyclohexenylene, 1,4-bicyclo-(2,2,2)-octylene, piperidine-1,4-diyl, naphthalene-2,6-diyl, decahydro-naphthalene-2,6-diyl, 1,2,3,4-tetrahydro-naphthalene-2,6-diyl, cyclobutane-1,3-diyl, spiro[3.3]heptane-2,6-diyl or dispiro[3.1.3.1]decane-2,8-diyl, it being possible for all these groups to be unsubstituted, mono-, di- tri- or tetrasubstituted with F, Cl, CN or alkyl, alkoxy, alkylcarbonyl or alkoxy carbony groups with 1 to 7 C atoms, wherein one or more H atoms may be substituted by F or Cl,

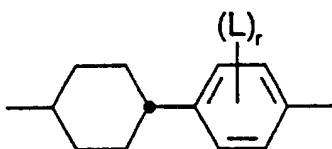
m

is 0, 1, 2 or 3.

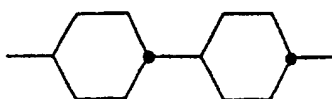
3. A bimesogenic compound as claimed in claim 1 or claim 2, characterized in that MG^1 and MG^2 are each independently selected from



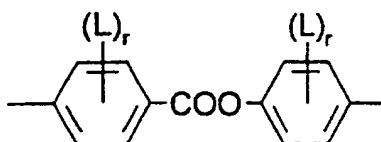
IIa



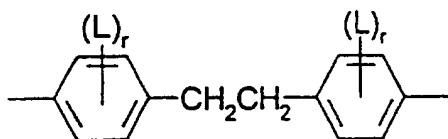
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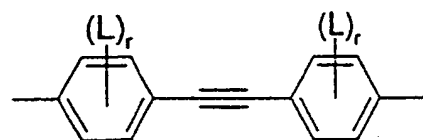
IIc



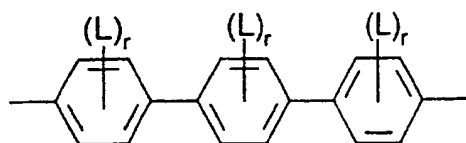
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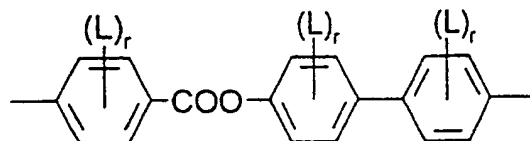
IIe



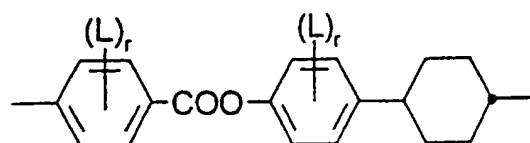
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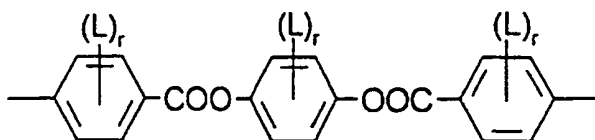
IIg



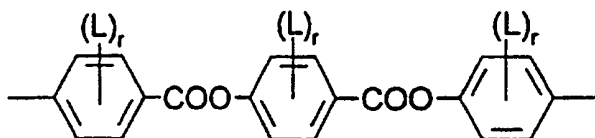
IIh



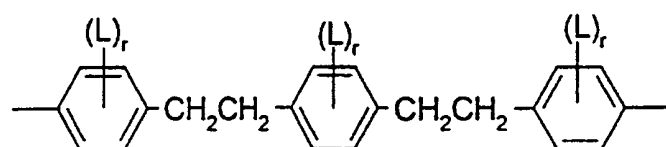
IIi



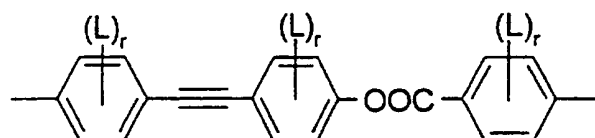
IIk



IIIm



IIIn



IIo

wherein L is F, Cl, CN, OH, NO₂ or an optionally fluorinated alkyl, alkoxy or alkanoyl group with 1 to 7 C atoms, and r is 0, 1 or 2.

4. A bimesogenic compound as claimed in any of claims 1 to 3, characterized in that R¹ and R² are each independently F, Cl, CN, NO₂, OCH₃, COCH₃, COC₂H₅, COOCH₃, COOC₂H₅, CF₃, C₂F₅, OCF₃, OCHF₂, or OC₂F₅.
5. A bimesogenic compound as claimed in any of claims 1 to 4, characterized in that Sp is -(CH₂)_o- and o is an integer from 5 to 15.
6. A bimesogenic compound substantially as hereinbefore described in the foregoing examples.

7. A bisomesogenic compound substantially as hereinbefore described with reference to the accompanying drawing.
8. Use of a bimesogenic compound as claimed in any of claims 1 to 7
5 in a liquid crystalline medium or a liquid crystal device.
9. A liquid crystalline medium comprising at least two components at least one of which is a bimesogenic compound as claimed in any of claims 1 to 7.
10
10. A liquid crystal device with a liquid crystalline medium comprising at least two components, at least one of which is a bimesogenic compound as claimed in any of claims 1 to 7.
11. A liquid crystal device as claimed in claim 10, characterized in that
15 it is a flexoelectric device.
12. A liquid crystal device as claimed in claim 10 or 11, characterized in that it comprises two plane parallel electrodes the inner surfaces of
20 which exhibit hybrid alignment conditions.



INVESTOR IN PEOPLE

Application No: GB 0023327.0
Claims searched: 1-12

Examiner: Stephen Quick
Date of search: 20 March 2001

Patents Act 1977 Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S):

Int Cl (Ed.7):

Other: Online: CAS ONLINE

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	US 4673529 A (CHISSO) 16.06.1987 & Chemical Abstracts, abstr no 106:205364, see abstract and compound RN 108178-32-1	1 & 2 at least
X	J. Mater. Chem., 1996, Vol. 6(5), pages 753-760 & Chemical Abstracts, abstr no 125:72473, see abstract and compound RN 178267-86-2	1 & 2 at least
X	Macromolecules, 1997, Vol. 30(5), pages 1521-1523 & Chemical Abstracts, abstr no 126:199900, see abstract and compound RN 187849-17-8	1 & 2 at least
X	Makromol. Chem., 1993, Vol. 194(1), pages 197-210 & Chemical Abstracts, abstr no 118:223280, see abstract and compound RN 147073-48-1	1 & 2 at least
X	Mol. Cryst. Liq. Cryst. Sci. Technol., Sect. A, 1995, Vol. 269, pages 39-53 & Chemical Abstracts, abstr no 123:257465, see abstract and compound RN 169391-46-2	1 & 2 at least
X	Thermochim. Acta, 1990, Vol. 164, pages 251-257 & Chemical Abstracts, abstr no 113:201924, see abstract and compound RN 130278-59-0	1 & 2 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.



INVESTOR IN PEOPLE

Application No: GB 0023327.0
Claims searched: 1-12

Examiner: Stephen Quick
Date of search: 20 March 2001

Category	Identity of document and relevant passage	Relevant to claims
X	Wiss. Z. - Martin-Luther-Univ. Halle-Wittenberg, Math.-Naturwiss. Reihe, 1989, Vol. 38(3), pages 15-25 & Chemical Abstracts, abstr no 112:129634, see abstract and compounds RN 125606-25-9 & 125606-37-3	1 & 2 at least
X	Chemical Abstracts, abstr no 129:316774 & Polym. Bull. (Berlin), 1998, Vol. 41(3), pages 267-274, see abstract	1 & 2 at least
X	Chemical Abstracts, abstr no 127:51062 & Vestn. S.-Peterb. Univ., Ser. 4: Fiz., Khim., 1996, Vol. (1), pages 96-103, see abstract	1 & 2 at least
X	Chemical Abstracts, abstr no 120:135359 & JP 050105875 A2 27.04.1993, see abstract	1 & 2 at least
X	Chemical Abstracts, abstr no 116:245708 & JP 030239788 A2 25.10.1991, see abstract	1 & 2 at least
X	Chemical Abstracts, abstr no 107:40443 & Polym. Commun., 1987, Vol. 28(3), pages 82-85, see abstract	1 & 2 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

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